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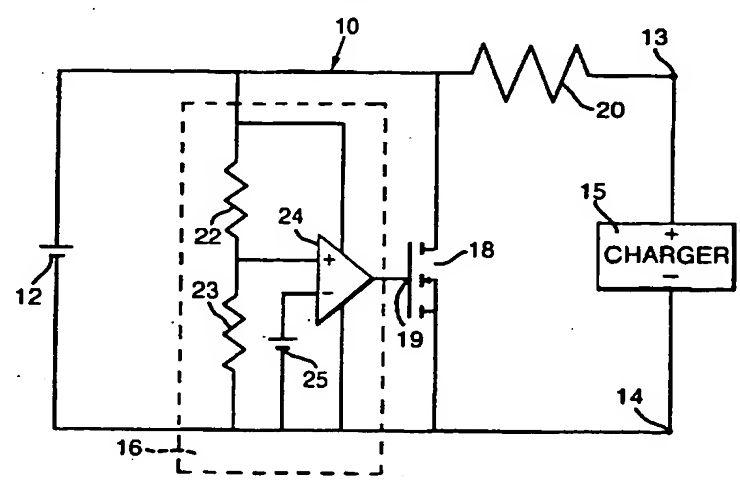
(54) Abstract Title
Preventing overcharge of lithium cells

(57) Overcharging of a lithium ion cell 12 is prevented by a heat-dissipating bypass component 18 connected in parallel with the cell 12, the current through the bypass 12 being negligible until the cell voltage rises above a threshold. The bypass 18 is in good thermal contact with a thermally responsive resistor 20 connected in series with the cell 12, so that when substantial current flows through the bypass 18, the temperature of resistor 20 is raised, so preventing significant further current flow through the cell 12. Resistor 20 may be a PTC resistor or a fuse. Bypass 18 may be a zener diode, or preferably a MOSFET controlled by an integrated circuit voltage monitor 16 having a temperature compensated reference voltage 25. Monitor 16 may have hysteresis, so that MOSFET 18 is turned on at a cell voltage of 4.7V and is turned off at a cell voltage of 4.5V; in this case MOSFET 18 may have a resistance of 20 ohms when turned on. Alternatively, monitor 16 may operate without hysteresis, MOSFET 18 then having a resistance of 1/4 ohm if it receives a full control signal.

The overcharge preventing circuit 16, 18, 20 may be incorporated in the cell 12 (Fig.2). An annular PTC resistor 18 may be sandwiched between steel disks (40), with MOSFET 18 soldered to one disk (40). The circuit 16,18 20 may be disposed in a recess at one end of a cylindrical steel casing (30) of the cell, being located between a top cap (36) of casing (30) and a contact plate (46) forming the external positive terminal of the cell. Alternatively, circuit 16, 18, 20 may be encapsulated in resin and located in the same space as a coil pack (32) consisting of the cell anode and cathode and separators.

Fig.1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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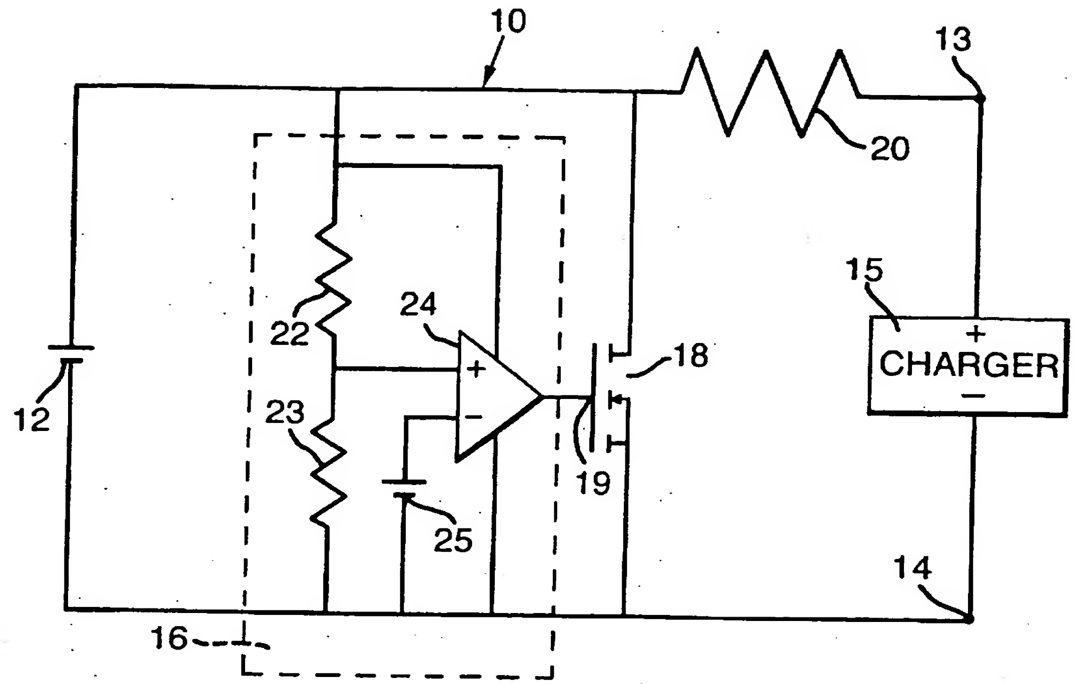
Fig.1.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CHARGER
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23
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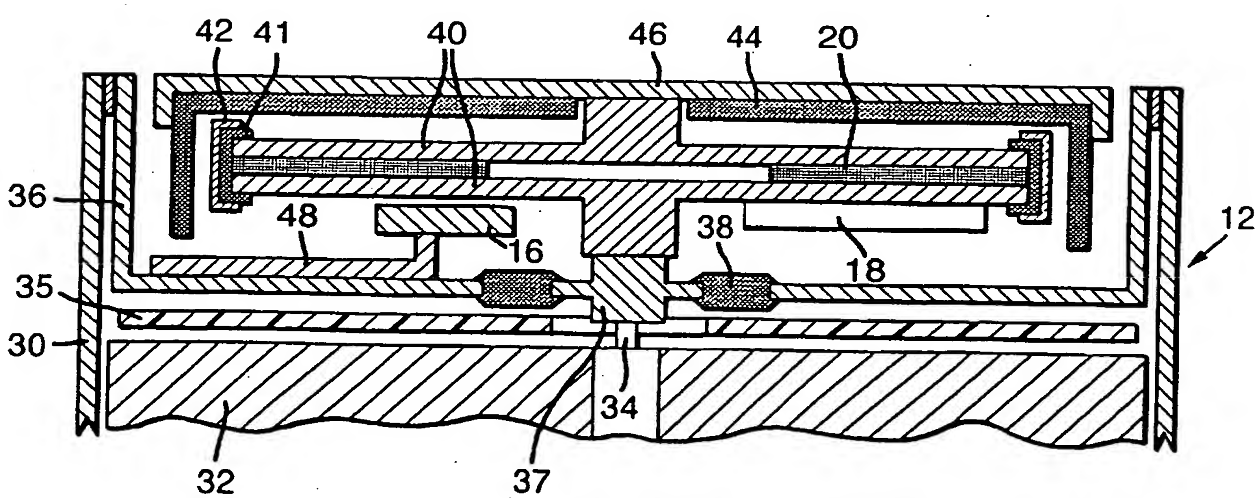
14
16

Fig.2.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Overcharge Prevention in Rechargeable Lithium Cells

This invention relates to a device for preventing overcharge of rechargeable lithium cells, and to a cell incorporating such a device.

Rechargeable cells based on lithium have recently become commercially available, these cells being referred to as lithium-ion or "rocking chair" cells, and these cells can provide both a high operating voltage and a high energy density. Such cells use two different insertion materials for the active cathode and anode materials. For example the active cathode material might be $LiCoO_2$ and the anode material be a form of carbon. During charging, lithium ions are withdrawn from the cathode material and inserted into the anode material, while during discharging lithium ions are withdrawn from the anode material and inserted into the cathode material. Such cells are safer than those which use metallic lithium.

If such lithium ion cells are overcharged, this may lead to deposition of metallic lithium on the anode; it may also result in heating of the cell, and can lead to thermal runaway or even fire. It is therefore necessary to prevent overcharging of such cells, and this is usually achieved by providing appropriate electrical circuitry within the battery charger to cease charging when the cell voltage reaches a safe value. It has also been suggested that individuals cells should incorporate a safety device, for example a disconnection device activated by a rise in the internal pressure within a cell during overcharge. It has also being suggested to include a positive temperature coefficient non-linear resistor (PTC) in series with such a cell, this being a

resistor whose resistance increases very markedly above a temperature threshold.

According to the present invention there is provided a device for preventing the overcharge of a lithium ion cell, the device comprising a thermally responsive resistor for connection in series with the cell, and a heat-dissipating bypass component for connection in parallel with the cell, the current through the bypass component being dependent upon the voltage of the cell such as to be negligible below a threshold voltage and increasing rapidly if the cell voltage exceeds that threshold voltage, and wherein the bypass component is in good thermal contact with the thermally responsive resistor.

The current through the bypass component will tend to discharge the cell, so reducing its shelf life; the current may be "negligible" either because it is less than other causes of self-discharge, or because the cell is being used in such a way that the reduction in shelf life is of no concern, for example because the cell is being recharged every day anyway. One option for the bypass component is a zener diode, as this allows very little current to flow up to the threshold voltage, and above the threshold voltage the current increases rapidly. However for cells of moderate capacity the leakage current with a zener diode below the threshold voltage may be unacceptably large, and so not "negligible". More preferably the overcharge prevention device also includes means for monitoring the voltage of the cell and for providing a control signal to the bypass component if the cell voltage exceeds the threshold voltage, and the bypass component is such that the current through it is controlled in response to the control signal.

Thus if the voltage of the cell exceeds the threshold voltage, then part of the charging current is arranged to flow through the bypass component, so dissipating heat, raising the temperature of the thermally responsive resistor, and so preventing further significant current flow through the cell. Cell overcharge is thus prevented. The thermally responsive resistor might be a fuse, or a PTC non-linear resistor. This device is preferably integral with the cell.

Hence, in a second aspect, the present invention provides a lithium ion cell with a casing, the casing defining external terminals of the cell, and enclosing the electrodes and the electrolyte of the cell; a thermally responsive resistor within the casing connected between an external terminal and a corresponding electrode of the cell, and a heat-dissipating bypass component within the casing connected in parallel with the cell, the current through the bypass component being dependent upon the voltage between the cell electrodes such as to be negligible below a threshold voltage and increasing rapidly if the cell voltage exceeds that threshold voltage, and wherein the bypass component is in good thermal contact with the thermally responsive resistor.

The bypass component is desirably a transistor such as a MOSFET, so that the current through this component is very small, for example less than a micro-amp, until the control signal is supplied to the gate of the MOSFET. If this occurs, then the current through the MOSFET will rise and it will carry most of the charging current, for example 1 A. Consequently it rapidly becomes hot, heating up the thermally responsive resistor. The voltage of the cell may be monitored by an integrated circuit which incorporates a resistor chain and a

temperature compensated reference voltage, and an amplifier to compare the voltage at a point on the resistor chain to the reference voltage. Such a circuit might typically draw about one micro-amp.

The voltage of such a cell with $LiCoO_2$ as the active cathode material might be expected to rise to 4.2 V during normal charging. In this case the bypass component might be arranged to draw current only if the cell voltage exceeds say 4.5 V. Thus in normal operation the bypass component will never draw current. Only if the charger develops a fault -- for example continuing to charge at a constant current -- will the cell voltage rise to this 4.5 V threshold. If this happens, the control signal will switch the MOSFET into low resistance, so some of the charging current will be taken by the MOSFET.

The invention will now be further and more particularly described, by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 shows a circuit diagram of an overcharge protection device; and

Figure 2 shows a sectional view of part of a cell incorporating the device of figure 1.

Referring now to figure 1, an overcharge protection device 10 is shown connected to a lithium ion cell 12; the cell 12 has external terminals 13, 14 which are connected to a charger 15. The lithium ion cell 12 might for example contain carbon in the form of heat treated mesocarbon microbeads as the active anode material, and $LiCoO_2$ as the active cathode material; in this case the voltage limits during normal operation would be 4.1 or

4.2 V when fully charged, and 2.75 V when discharged. Such a cell would be recharged at a constant voltage with a current limit - that is to say the charger 15 would be set to provide a voltage of 4.2 V, but that the current should not exceed say 2 A. Initially the charging current would be the constraining factor, but once the cell has reached 4.2 V the voltage would remain constant while the current would gradually decrease. That presumes that the charger 15, and any external safety circuits (not shown) associated with the cell, operate correctly.

The overcharge protection device 10 incorporates a voltage monitoring device 16 connected between the electrodes of the cell 12, a MOSFET 18 also connected between the electrodes of the cell 12, and a PTC non-linear resistor 20 connected between the cathode of the cell 12 and the corresponding external terminal 13 of the cell 12. The monitoring device 16 provides a control signal to the gate 19 of the MOSFET 18. The MOSFET 18 is in good thermal contact with the PTC non-linear resistor 20.

The monitoring device 16 is an integrated circuit which incorporates a potential divider defined by two resistors 22, 23 in series, a differential amplifier 24 with one input terminal connected to the junction of the resistors 22 and 23, and a temperature compensated reference voltage 25 connected to the other input terminal of the amplifier 24. For example the monitoring device might be a Motorola MC 33464; this device incorporates positive feedback so the threshold voltage at which it provides a control signal to the MOSFET 18 (which might be set at say 4.7 V) is higher than the voltage at which the control signal is turned off (which might be say 4.5 V). This device 16 thus incorporates hysteresis.

If the cell voltage increases to 4.7 V, the amplifier 24 provides a signal to the gate 19 of the MOSFET 18, so the MOSFET becomes a low resistance of for example 20 Ω. Consequently some of the charging current flows through the MOSFET 18 rather than the cell 12. The voltage between the electrodes of the cell 12 will therefore decrease slightly. (If the voltage decreases to 4.5 V the control signal will be turned off, but that will increase the current through the cell, and raise the cell voltage back to 4.7 V, so the control signal will be turned on again, and this process will repeat, so pulses of current will flow through the MOSFET 18.) The MOSFET 18 becomes hot, so heating the PTC non-linear resistor 20 to above 80°C. The resistor 20 changes to high resistance, so preventing further charging of the cell 12. The current from the charger 15 is very much reduced, and this small current bypasses the cell 12 through the MOSFET 18; the heating effect of this small current tends to maintain the resistor 20 in its high resistance state.

An alternative monitoring device 16 does not incorporate positive feedback (and so hysteresis). In this case the MOSFET 18 would be one whose resistance would become even lower - say ¼ ohm - if it were to receive a full voltage control signal from the device 16, but the control signal would actually be just enough to hold the cell voltage at the threshold value, which might be set at 4.5 V. In other respects this circuit operates in the same way as that described above, as the current through the MOSFET heats it up.

Referring now to figure 2, there is shown a sectional view of one end of a lithium ion rechargeable cell 12 incorporating the device of figure 1. The cell 12 is of generally cylindrical shape, with a tubular

stainless steel casing 30 within which is enclosed a coil pack 32 consisting of an anode, a separator, a cathode, and a separator rolled up to form the pack 32. The anode is connected electrically to the casing 30 at the other end of the cell 12. At the end shown, a cathode tag 34 projects from the centre of the coil pack 32. Above the coil pack 32 (as shown) is an insulated washer 35, above which is a stainless steel top cap 36 at whose centre is a stainless-steel contact pin 37 supported by a glass seal 38. The cathode tag 34 is welded to the contact pin 37. The top cap 36 has a peripheral flange welded around its edge to the edge of the casing 30. An annular non-linear positive temperature coefficient resistor 20 is sandwiched between two steel disks 40, these components being held together by a plastic rim 41 and a steel clip 42, and the resulting assembly is welded to the top of the contact pin 37, covered by a plastic cap 44, and welded to a steel contact plate 46.

It will thus be appreciated that the contact plate 46 acts as the external positive terminal of the cell 12 (marked as 13 in figure 1), and that the PTC resistor 20 is electrically in series between the cathode tag 34 and the contact plate 46. The MOSFET 18 is soldered to the lower face of the lower disk 40, to ensure good thermal contact, and is connected electrically (as described in relation to figure 1) to the monitoring circuit 16 which locates in the annular space between the top cap 36 and the lower disk 40 and is electrically connected by a lead 48 to the top cap 36. Both the MOSFET 18 and the monitoring circuit 16 are connected electrically between the top cap 36 (which is connected to the anode of the cell) and to the lower disk 40 (which is connected to the cathode of the cell).

It will be appreciated that the overcharge protection device 10 might be incorporated within a cell casing in a different fashion to that described in relation to figure 2, for example it might be encapsulated in resin, and locate in the same space as the coil pack 32. It will also be appreciated that an overcharge protection device may differ from that described, for example in using a fuse in place of the PTC resistor 20; or by using different electronic components for the monitoring circuit 16. For example the cell voltage might be monitored by a circuit incorporating two discrete resistors 22 and 23, and the amplifier 24 and voltage reference 25 might be provided by an integrated circuit (for example of the type MAX 921). Furthermore the signal provided to the gate 19 of the MOSFET 18 might be smoothed by a filter, for example using a resistor and a capacitor.

The PTC resistor must have a large enough cross-sectional area to be able to carry the maximum cell output current in normal operation. Nevertheless it might not be annular (as described in relation to Figure 2). For example the PTC resistor might be an annular sheet with a portion cut out; the PTC resistor might be sandwiched between steel disks, as in Figure 2, and in this case the MOSFET 18 may be located between these disks in the space provided by the cut out portion. This arrangement of the MOSFET within the PTC resistor assembly enables the height occupied by the overcharge protection device 10 to be reduced.

Claims

1. A device for preventing the overcharge of a lithium ion cell, the device comprising a thermally responsive resistor for connection in series with the cell, and a heat-dissipating bypass component for connection in parallel with the cell, the current through the bypass component being dependent upon the voltage of the cell such as to be negligible below a threshold voltage and increasing rapidly if the cell voltage exceeds that threshold voltage, and wherein the bypass component is in good thermal contact with the thermally responsive resistor.

2. A device as claimed in claim 1 wherein the thermally responsive resistor comprises a PTC non-linear resistor.

3. A device as claimed in claim 1 or claim 2 also comprising means for monitoring the voltage of the cell and for providing a control signal to the bypass component if the cell voltage exceeds the threshold voltage, and the bypass component is such that the current through it is controlled in response to the control signal.

4. A lithium ion cell with a casing, the casing defining external terminals of the cell, and enclosing the electrodes and the electrolyte of the cell; means within the casing for suppressing the flow of charging current through the cell if the voltage between the cell electrodes exceeds a threshold value.

5. A cell as claimed in claim 4 wherein the suppressing means comprises a thermally responsive resistor within the casing connected between an external terminal and a corresponding electrode of the cell, and a heat-

dissipating bypass component within the casing connected in parallel with the cell, the current through the bypass component being dependent upon the voltage between the cell electrodes such as to be negligible below a threshold voltage and increasing rapidly if the cell voltage exceeds that threshold voltage, and wherein the bypass component is in good thermal contact with the thermally responsive resistor.

6. A cell as claimed in claim 5 wherein the thermally responsive resistor comprises a PTC non-linear resistor.

7. A cell as claimed in claim 5 or claim 6 also comprising means within the casing for monitoring the voltage between the cell electrodes and for providing a control signal to the bypass component if the cell voltage exceeds the threshold voltage, and the bypass component is such that the current through it is controlled in response to the control signal.

8. A cell as claimed in claim 7 wherein the bypass component is a transistor.

9. A cell as claimed in claim 8 wherein the bypass component is a MOSFET.

10. A cell as claimed in any one of claims 7 to 9 wherein the voltage of the cell is monitored by an integrated circuit which incorporates a resistor chain and a temperature compensated reference voltage, and an amplifier to compare the voltage at a point on the resistor chain to the reference voltage.

11. A lithium ion cell substantially as hereinbefore

described with reference to, and as shown in, the accompanying drawings.

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Application No: GB 9909100.1
Claims searched: 1 to 3

Examiner: M J Billing
Date of search: 1 July 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1B B1044, B1046; H2H HBCD.

Int Cl (Ed.6): H01M 10/44, 10/46; H02H 7/18; H02J 7/00, 7/04, 7/10.

Other: ONLINE - EPODOC, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US5875085	(TEXAS INSTRUMENTS) - Fig.1; column 2 lines 57-59, column 6 lines 66-67, column 8 lines 25-27, column 11 lines 34-39	1-3
X	US5703463	(NATIONAL SEMICONDUCTOR) - Fig.6; column 4 lines 54-56, column 9 line 51 to column 10 line 5	1-3
A	WO95/00993A1	(BOLDER) - Fig.1; page 6 line 4 to page 7 line 10	1
X	JP100056742	(MATSUSHITA) - Figs.1-3 & WPIi Abstract Accession No.98-204105 [18]	1-3
X	JP100051962	(SONY) - Figs.1,4 & WPI Abstract Accession No.98-200350 [18]	1-3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.